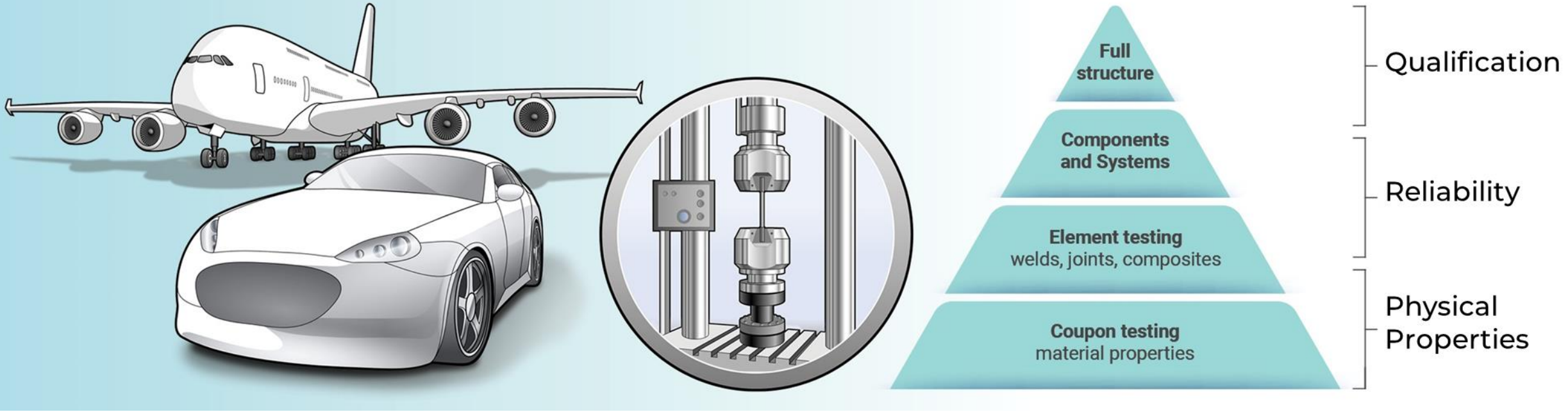

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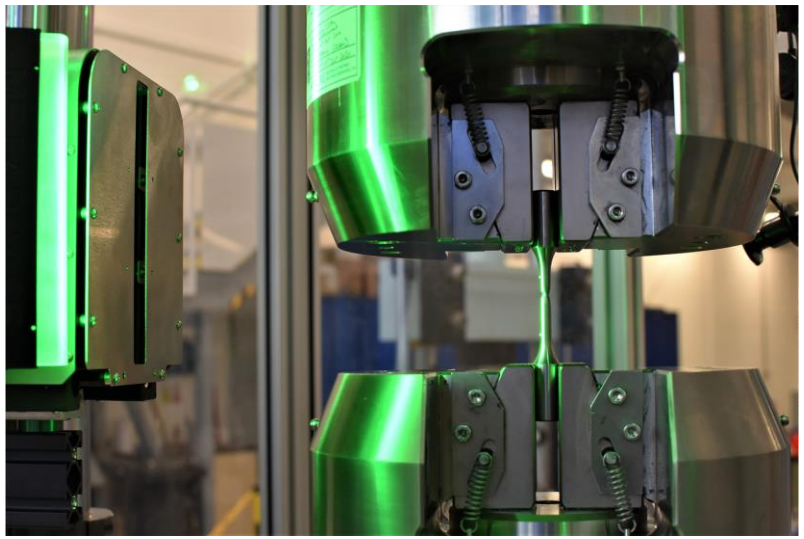

- **Materials testing and characterisation for modern engineered materials and structures**

Dr. Michelle Hill,
Head of Materials Testing, HBK

Materials testing and characterisation for modern engineered materials and structures

Abstract

- Any fatigue analysis is only as good as the materials data it is based on. For durable lightweight structures made with new construction techniques or material types, it can be a challenge to find high quality fatigue data. HBK's Advanced Materials Characterisation and Testing (AMCT) facility in the UK has extensive experience in standard and novel fatigue and durability testing. This presentation will illustrate how modern testing methods can improve fatigue prediction of engineered structures with new joining techniques, additively manufactured materials, and composites.

About the presenter, Dr. Michelle Hill, Head of Materials Testing, HBK

- Michelle holds a Master's degree in Aeronautical Engineering and a PhD studying the damage resistance and tolerance of composite sandwich structures, obtained from Loughborough University. She joined HBK in May 2017, having previously held the position of Chief of Materials at the Rolls-Royce CTAL facility on the Isle of Wight. Her speciality is in composite materials characterisation and testing, with hands-on experience in defining and executing large material qualification programmes.
- Having spent 10 years on the Rolls-Royce composite fan system programme, leading the Materials team, Michelle has experience of how to relate materials testing to real applications and how to characterize difficult structures such as hybrid joints. At HBK she is responsible for the AMCT facility and the management of the commercial testing activities along with research into the fatigue behaviour of additively manufactured materials and composites.

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Materials Testing and Characterisation for Modern Engineered Materials and Structures

2023 HBK TECHNOLOGY DAYS

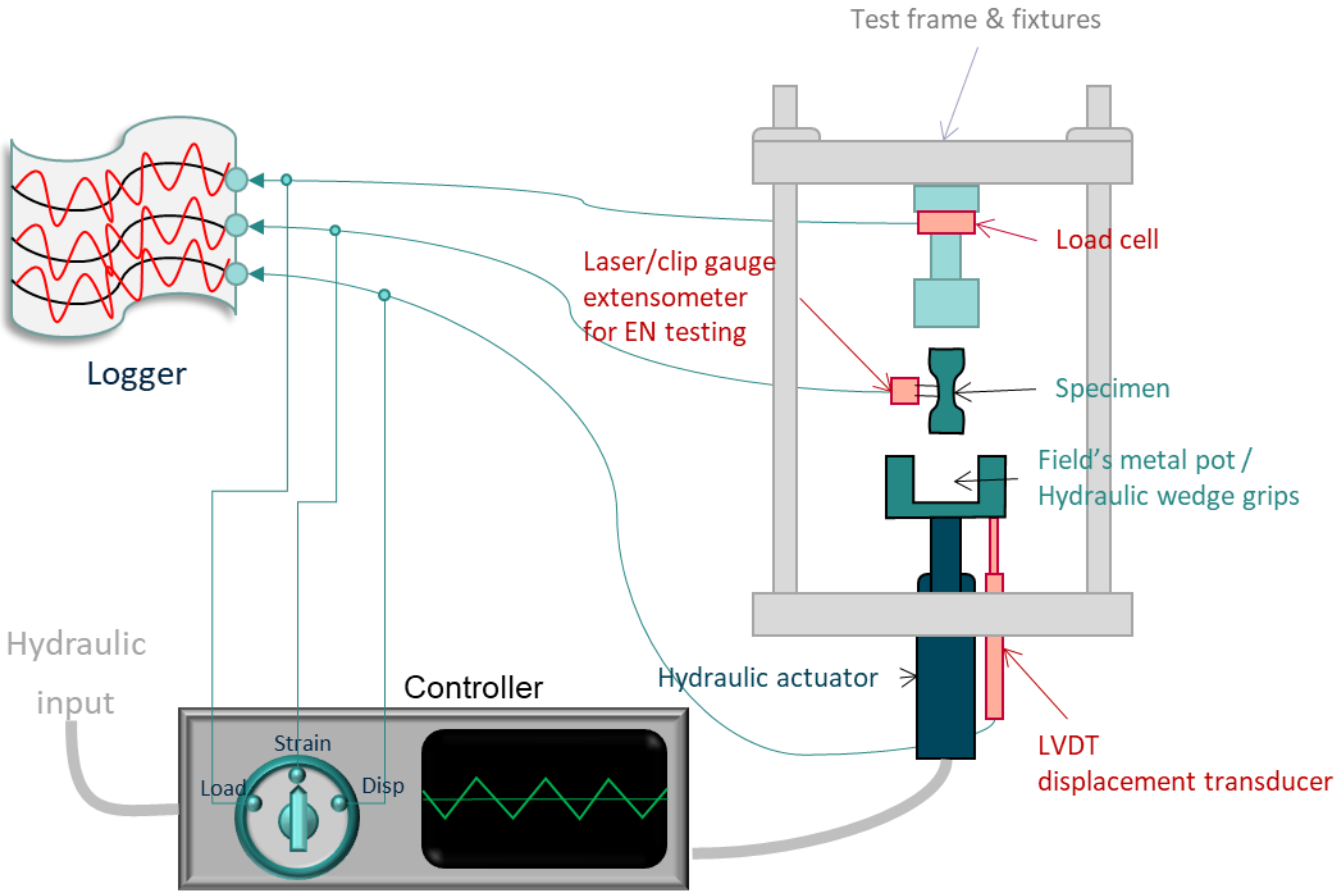
Presenter: Dr Michelle Hill

Head of Materials Testing

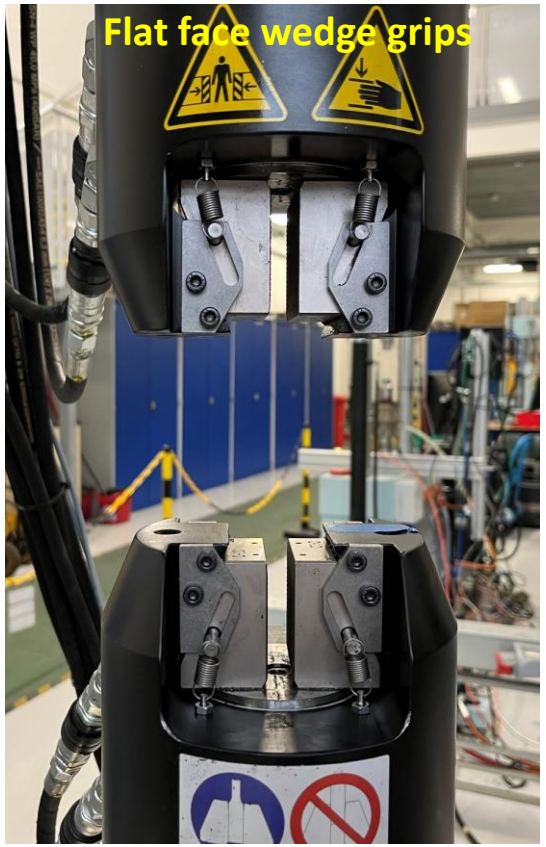
Agenda

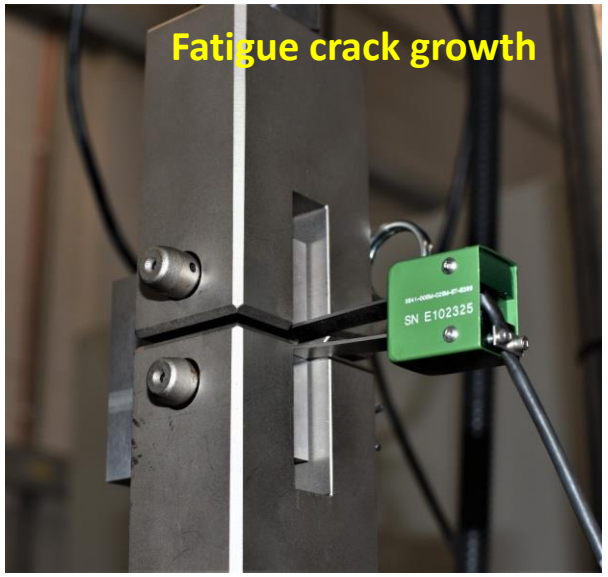
1. Overview of fatigue testing equipment (coupon testing)
2. Measurement uncertainty
3. How to ensure sources of uncertainty are accounted for
4. Case study: Additively manufactured titanium

Equipment for Fatigue Testing

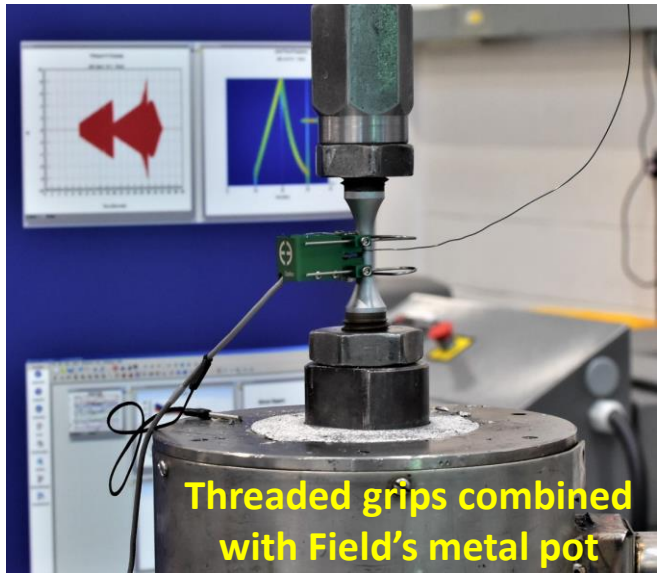


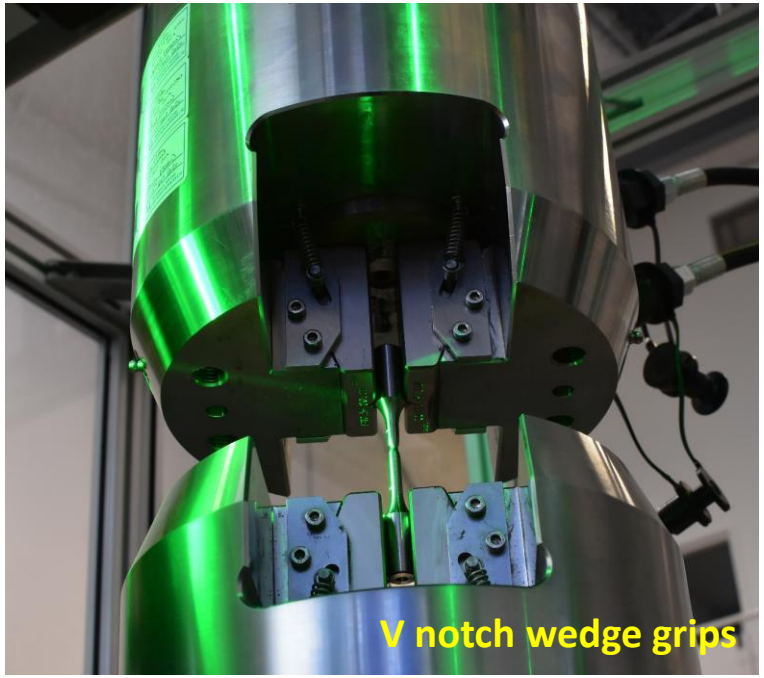
Grips and Fixtures


Flat face wedge grips



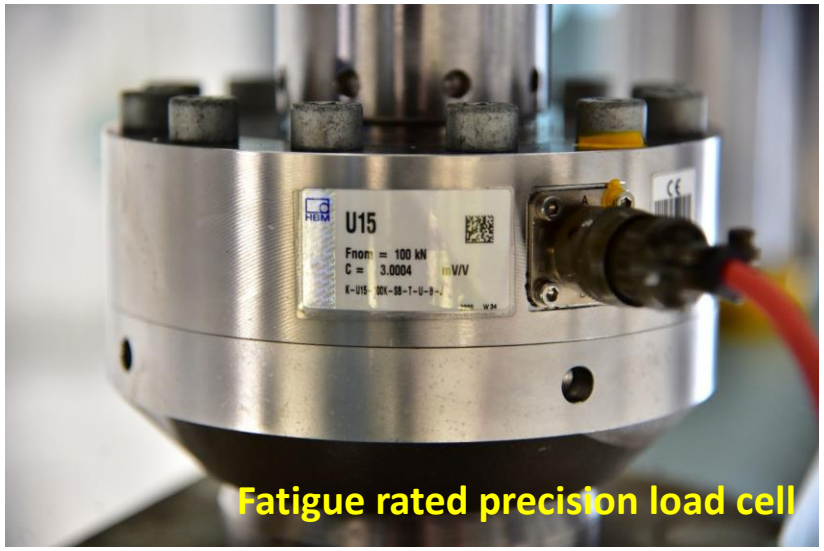
Fatigue crack growth

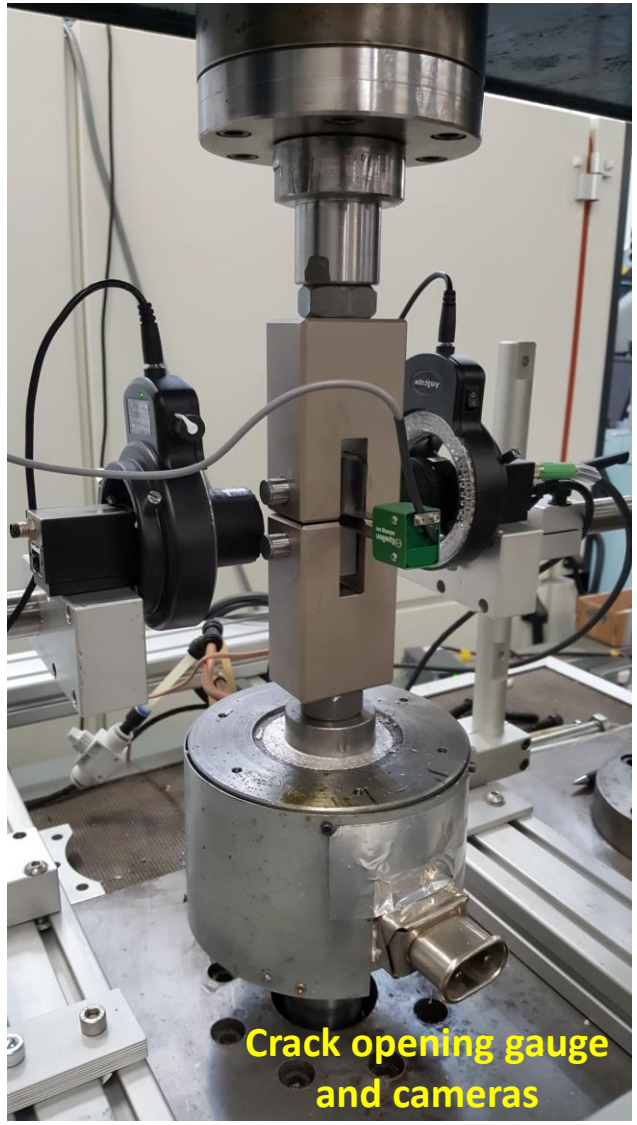

Threaded grips combined with Field's metal pot

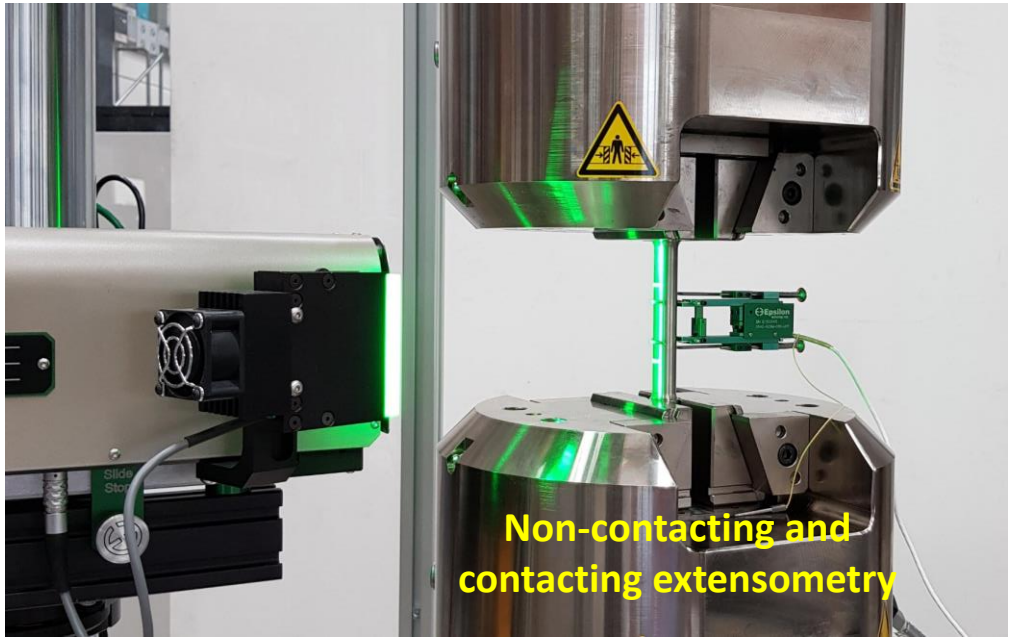

V notch wedge grips

Flat sheet test fixture with anti-buckling guides and Field's metal pot

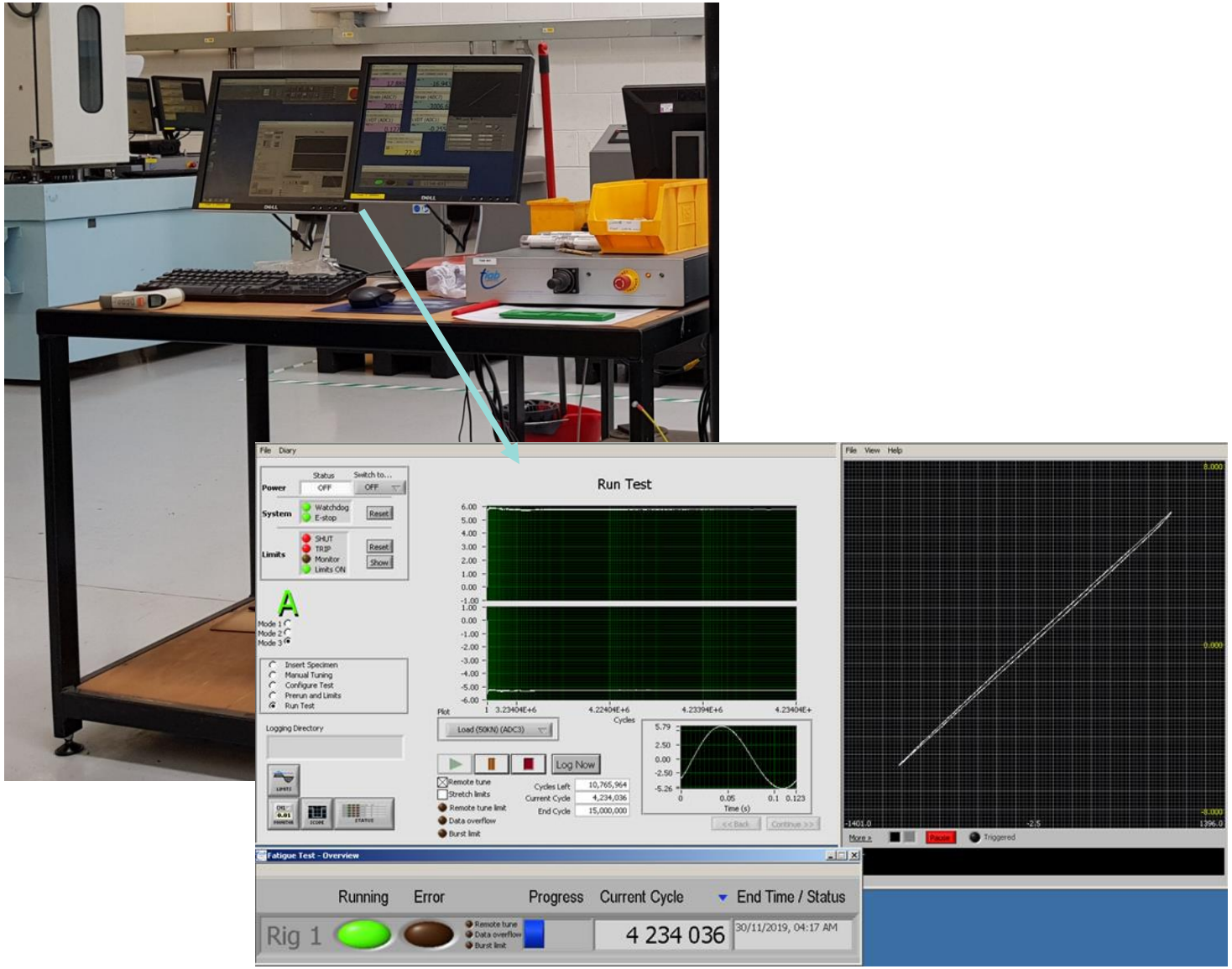
Measurement Devices







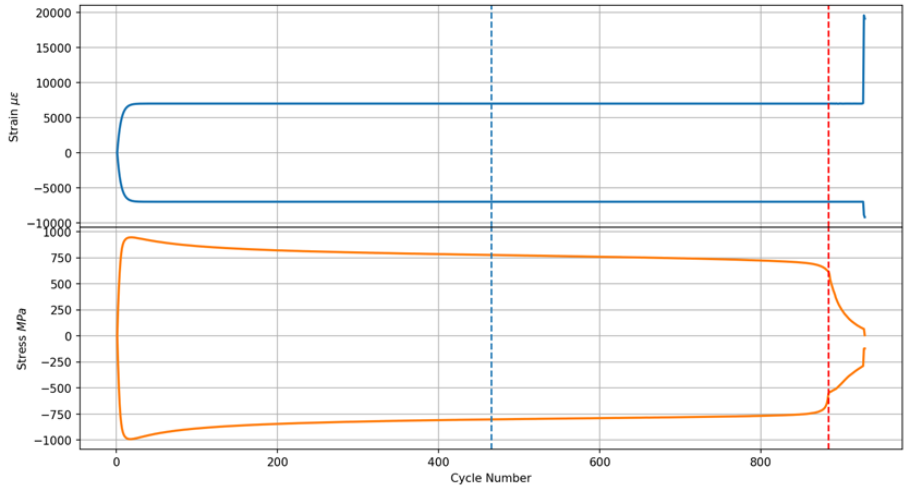
Controllers and Data Capture

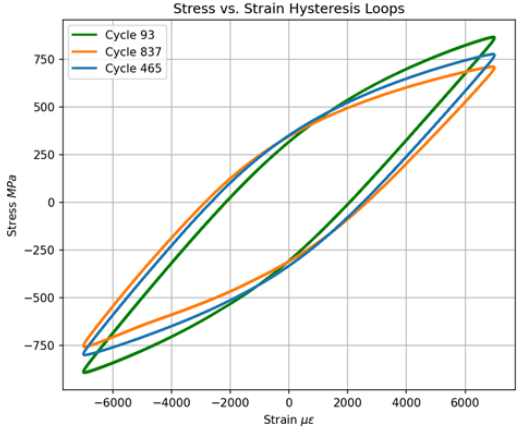


Strain Controlled Fatigue Test Report

HBK HOTTINGER BRÜEL & KJÆR

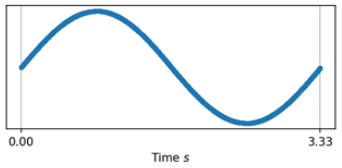
Job reference:	C12345	Material:	Sample Material
Test number:	11	Customer:	HBK AMCT
Test date:	21/10/2020	Engineer:	MC
Software version:	3.0.1	Test rig:	Emily (Tiab)





Cross sectional area:	16.100 mm^2
Test temperature:	Ambient
Test frequency:	0.3 Hz
Stable loop:	465
Cycles to separation:	929
5% load drop:	740
10% load drop:	858
20% load drop:	884
50% load drop:	893

Waveform



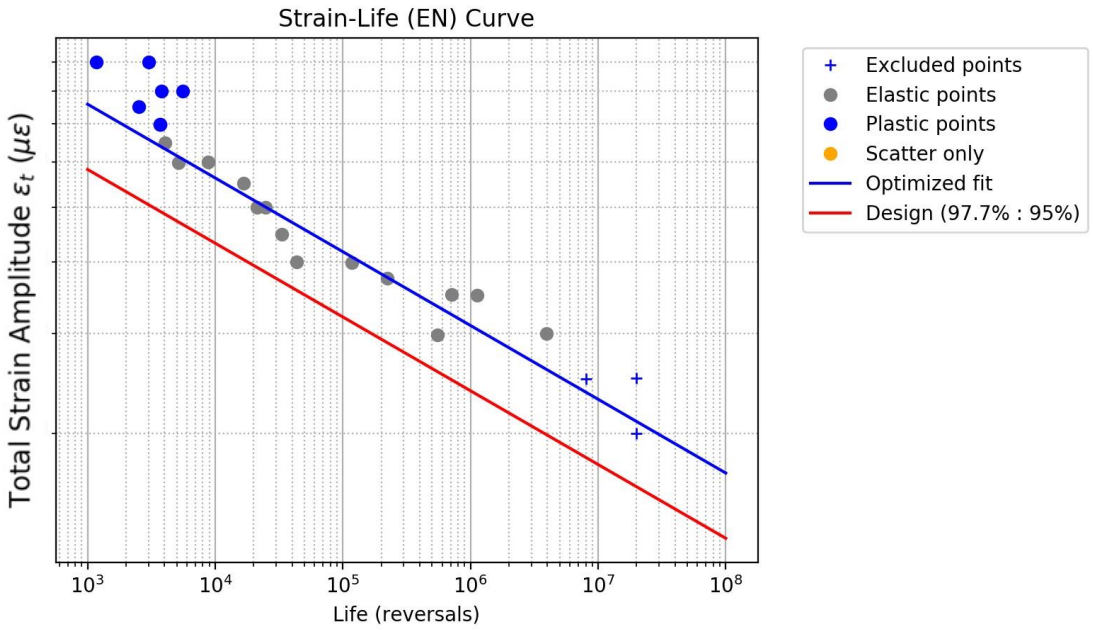
Cycle No.	Total Stress	Total Strain	Elastic Strain	Plastic Strain
93	1758.5 *MPa*	14000	9780	4220
465	1577.1 *MPa*	13999	8817	5182
837	1468.4 *MPa*	14000	8496	5504

HBK HOTTINGER BRÜEL & KJÆR

Agenda

1. Overview of fatigue testing equipment (coupon testing)
2. **Measurement uncertainty**
3. How to ensure sources of uncertainty are accounted for
4. Case study: Additively manufactured titanium

Measurement Uncertainty



There are two types of uncertainty in materials testing:

Epistemic

- Can be reduced by increased knowledge
- e.g. measurement equipment accuracy

Aleatoric

- These are irreducible errors
- e.g. material scatter due to natural causes

Epistemic uncertainty needs to be reduced

Sources of Variability Relating to Equipment

Fixturing:

1. Alignment of load train and fixturing
2. Alignment of specimen within fixturing
3. Buckling of specimen under compressive loading
4. Fretting of specimen with anti-buckling guides

Load Cell:

1. Calibration (ISO Class 0.5)
2. Operating below range of calibration (generally <1% of max load)
3. Large variations in ambient temperature

Extensometry:

1. Calibration (Class B2 or better)
2. Misalignment
3. Inaccurate positioning
4. Large variations in ambient temperature
5. Crack location relative to extensometer

Control Settings:

1. Too high a frequency causing self-heating of specimen
2. Too high a frequency for material response
3. Insufficient data capture
4. Poor tuning of controller (PID, gain etc)

Sources of Variability Relating to Specimens

Geometrical Accuracy:

1. Concentricity / Symmetry
2. Thread accuracy
3. Constant gauge section (no taper)
4. Undercuts at gauge to radius transition or machining steps

Surface Quality:

1. Localised damage such as scratches
2. Overall surface roughness
3. Edge finish

Material:

1. Extraction direction
2. Internal defects
3. Residual Stresses
4. Batch to Batch variation

These could be considered Aleatoric

Agenda

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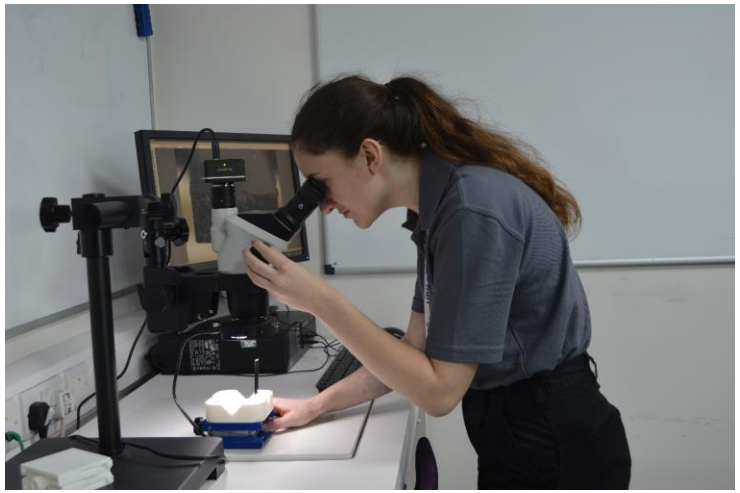
Quality Control During Testing

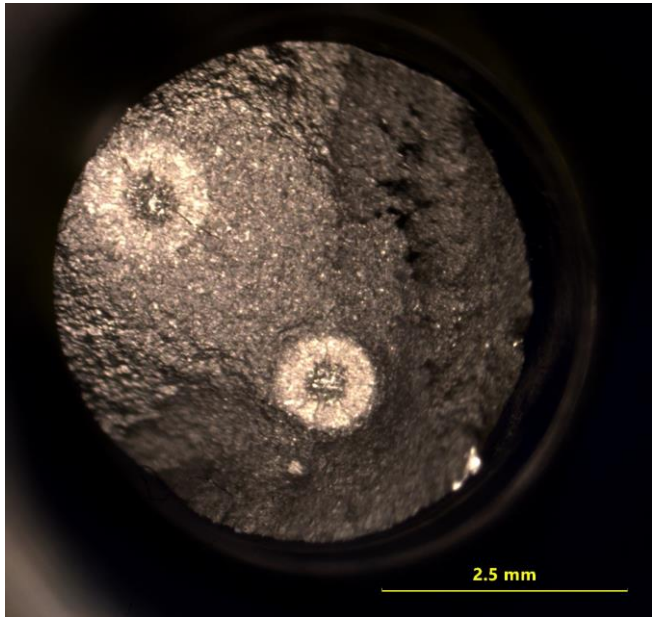
- Specimen inspection
- Equipment calibration
- Test set-up
- Checks against existing data

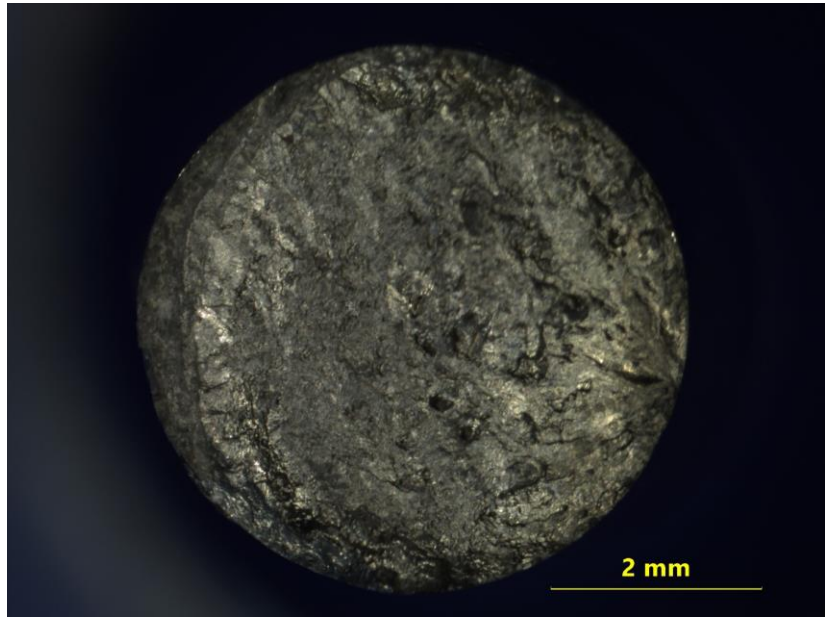
Examination of Fracture Surfaces



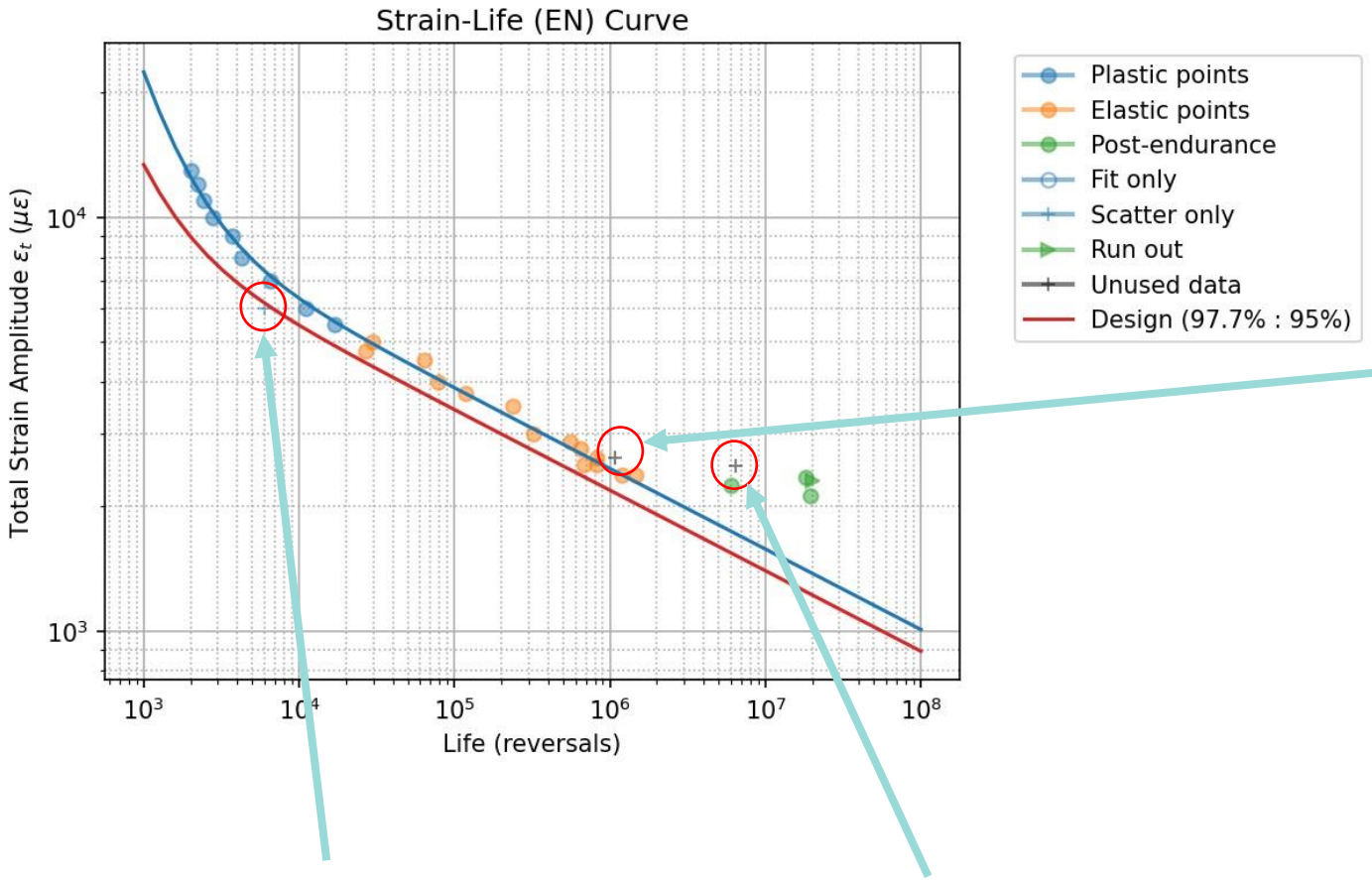
Visual inspection of fracture surfaces to:

1. Check failure was within gauge section
2. Identify failure initiation location
3. Look for presence of any internal or surface defects



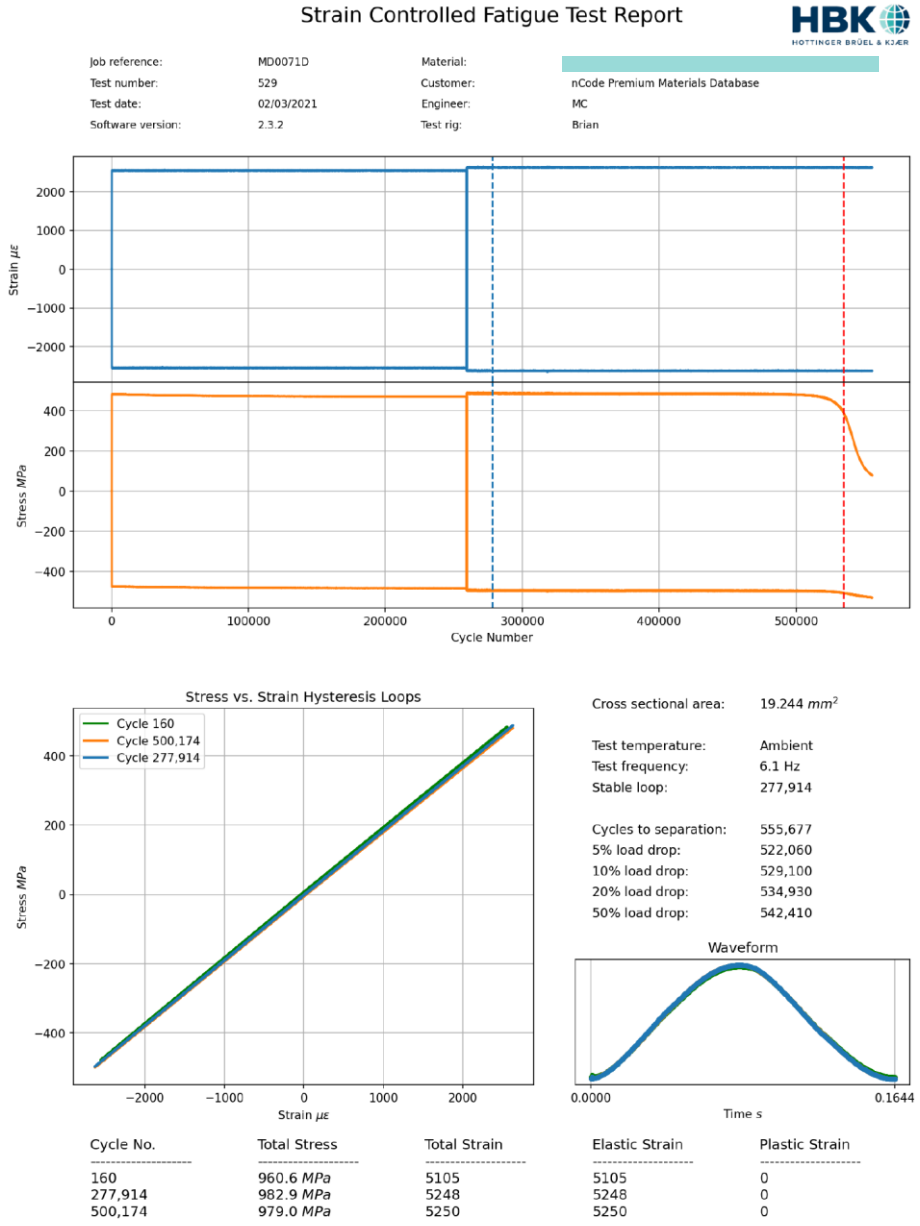


Examination of Recorded Data



Failure location in radius of specimen due to internal defect (local irregularity)

Extensometer misaligned (observed during testing)



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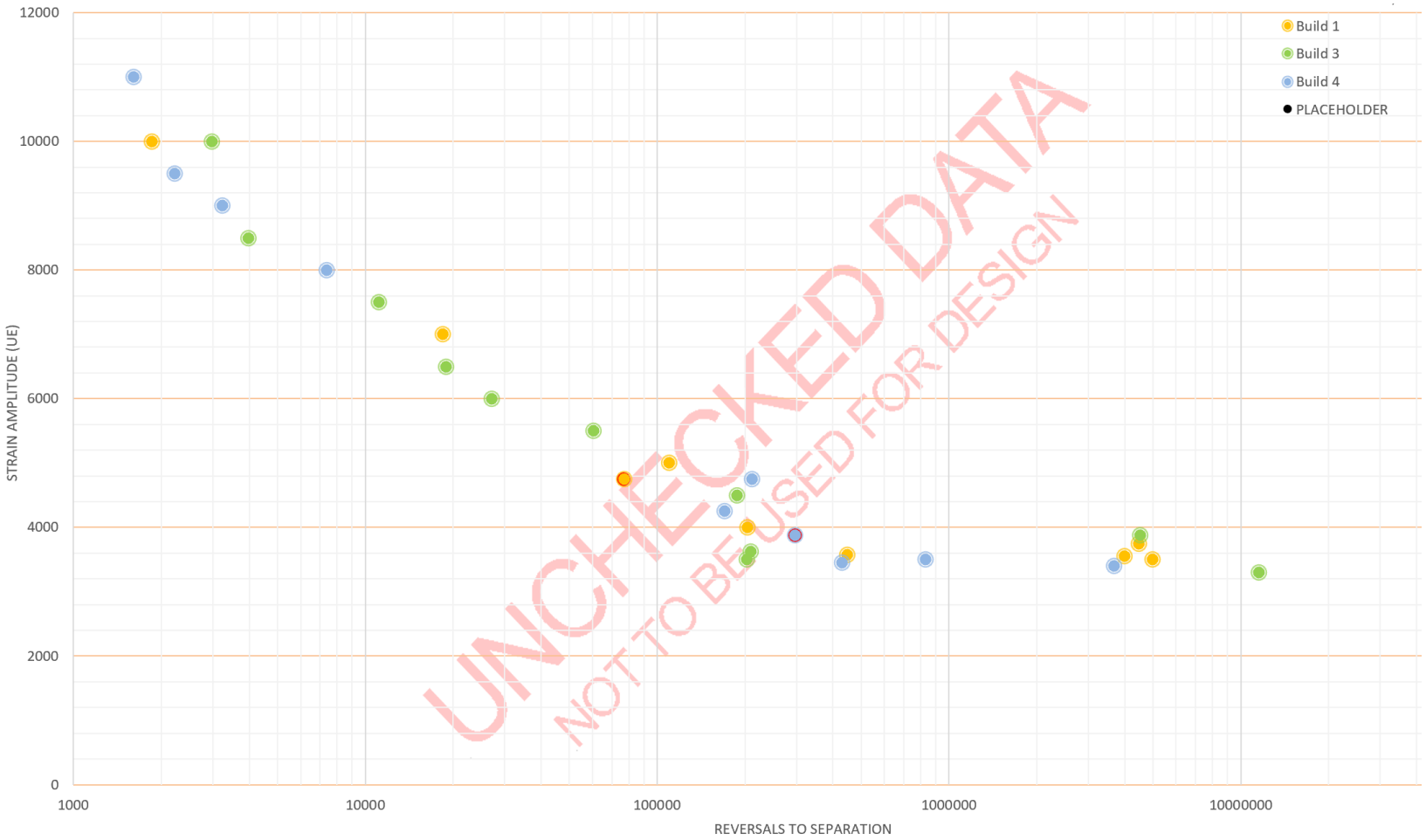
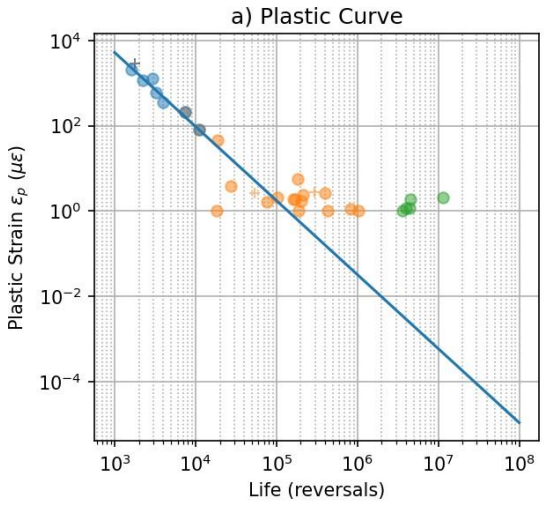
4. **Case study: Additively manufactured titanium**

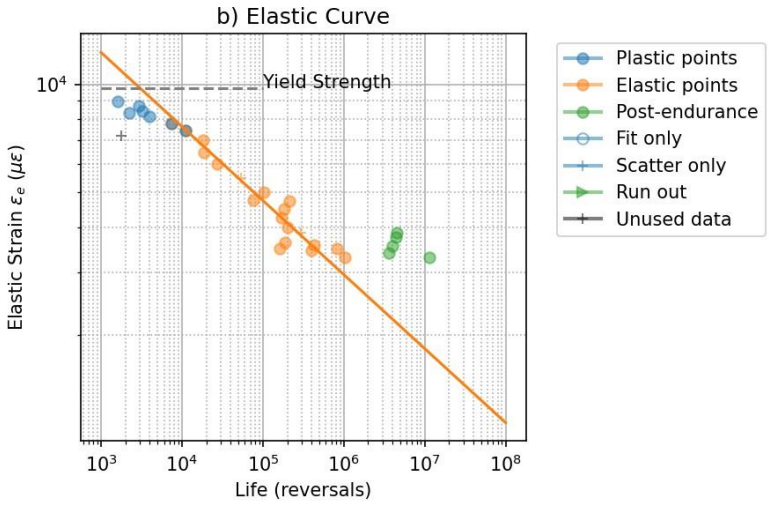
Case Study – Additively Manufactured Titanium

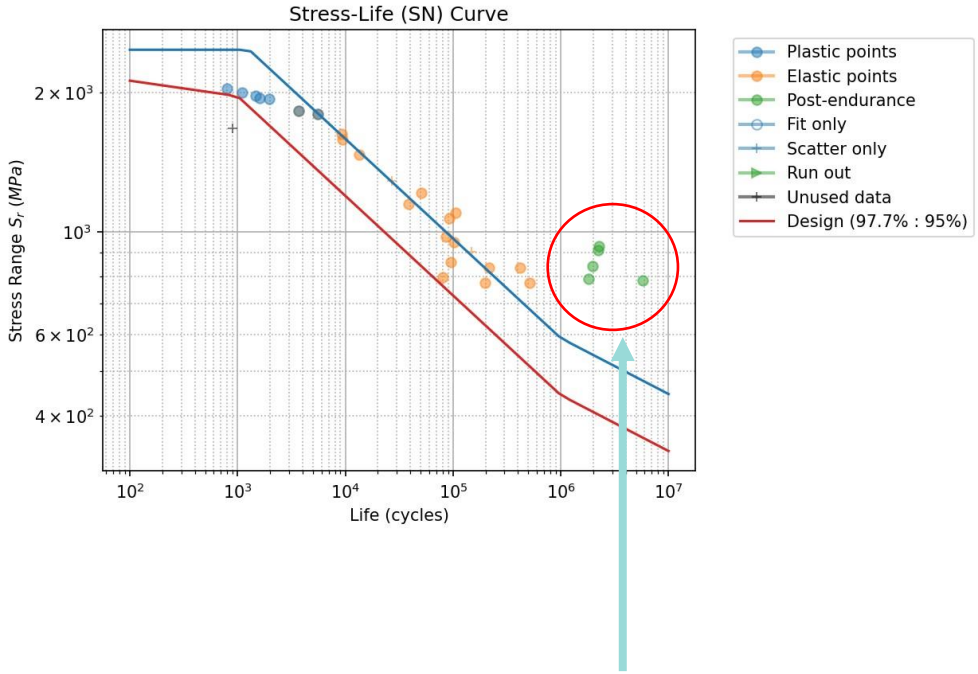
Data from test rig based on separation/test stopped



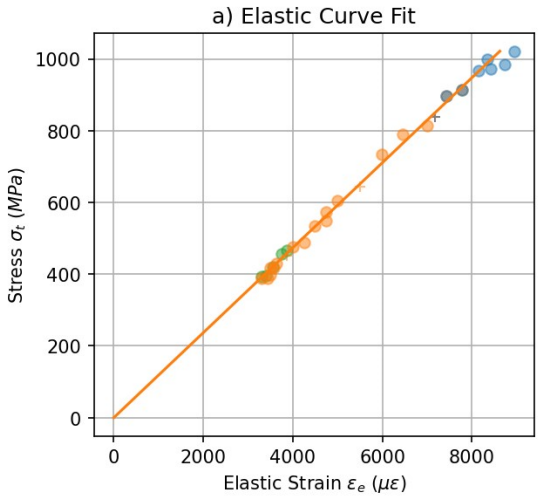
Case Study – Additively Manufactured Titanium

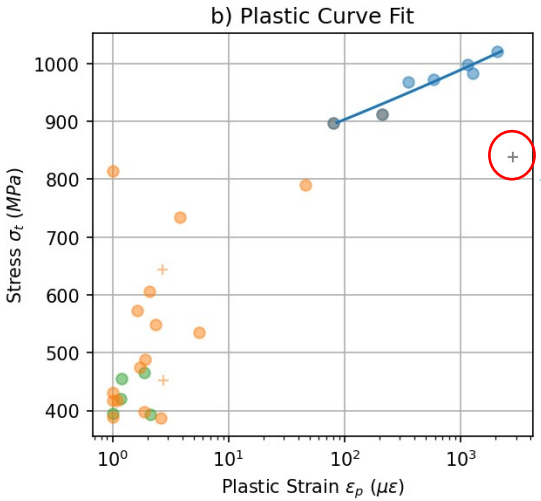




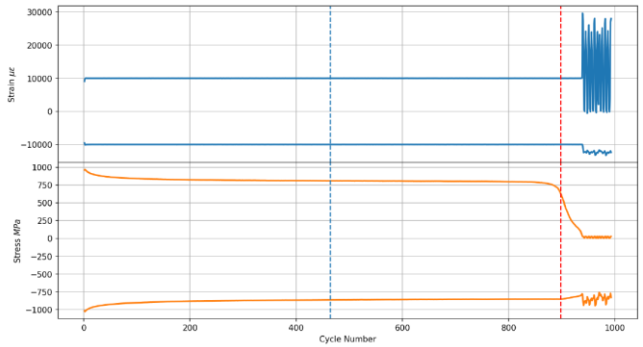


Indicates presence of endurance limit

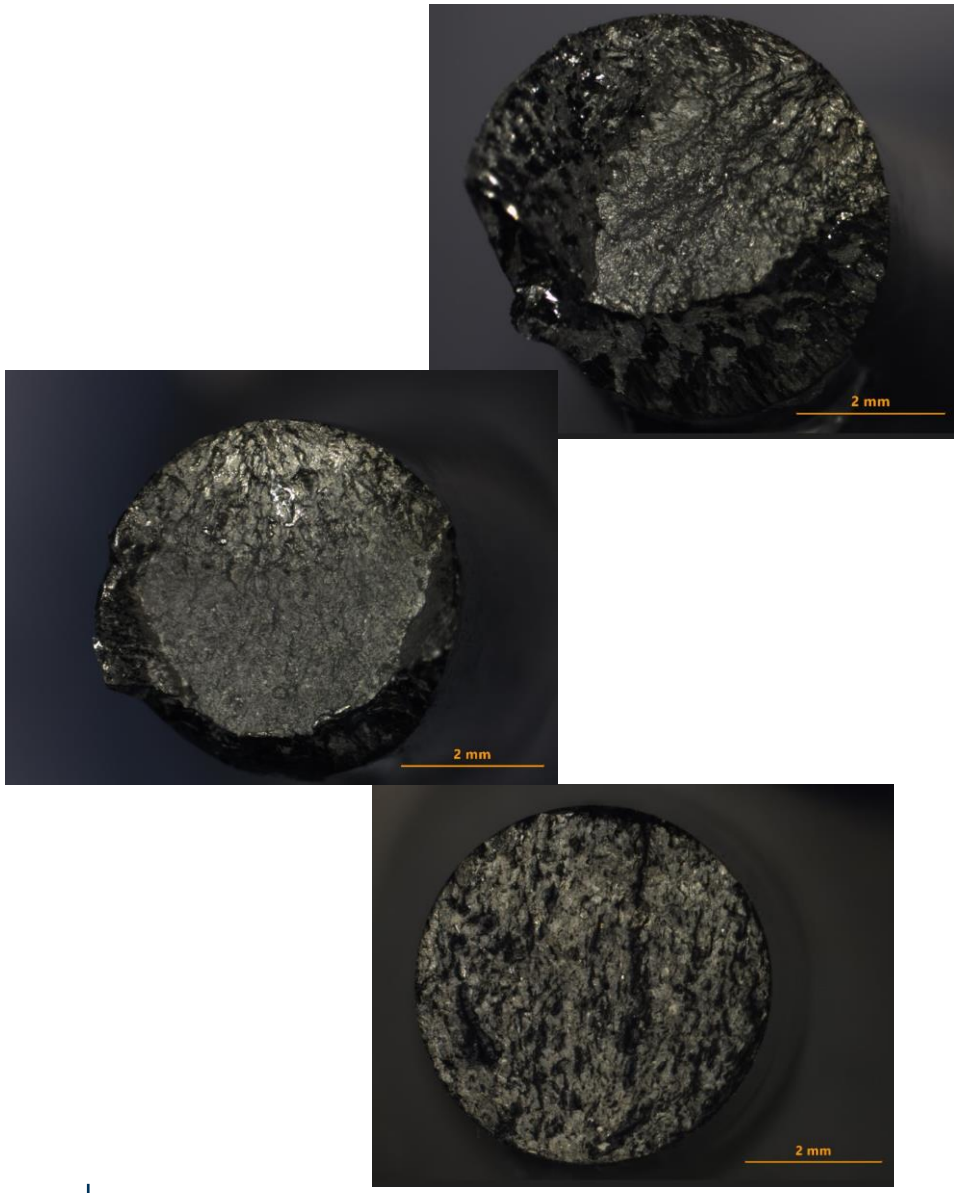


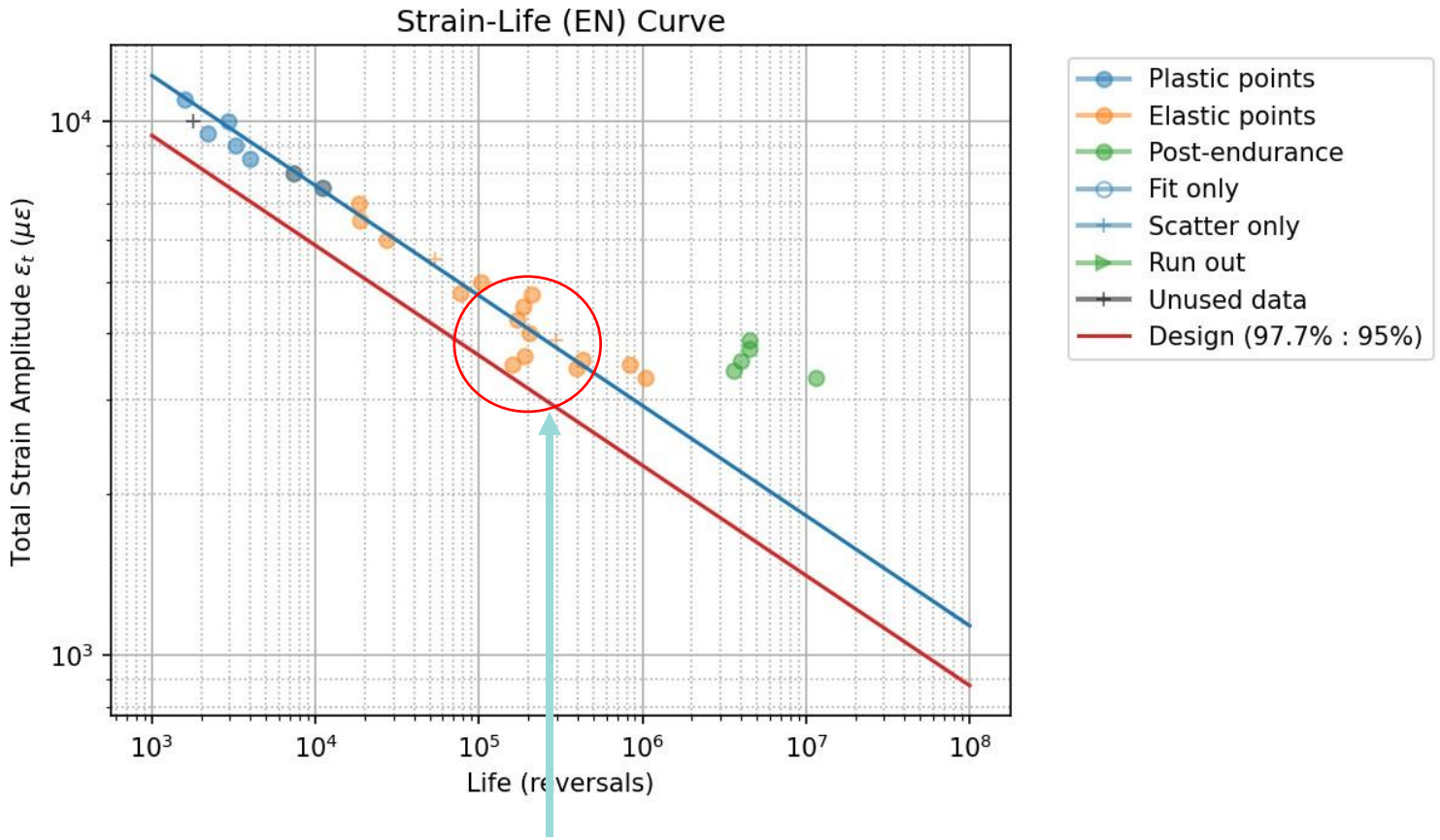


This point is out of family



Case Study – Additively Manufactured Titanium





Natural variation due to nature of material, therefore must be included in generation of the design curve.

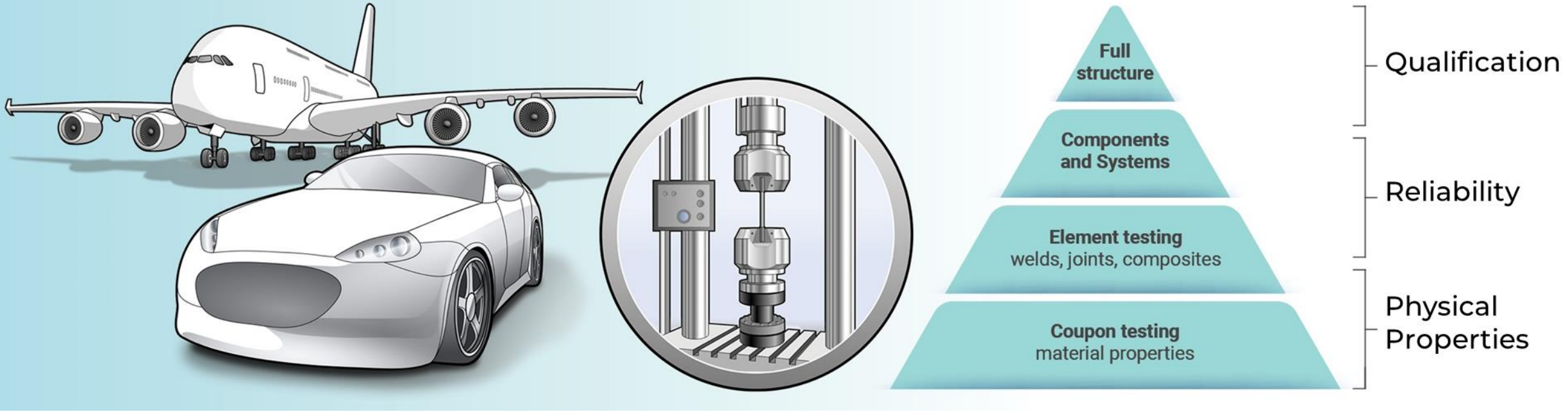
Summary

- Modern testing methods can be used to improve fatigue prediction of engineered structures by focusing on the quality of the material data collected.
- There are many possible sources of measurement uncertainty and this can have a direct effect on the CAE Design allowables.
- When obtaining fatigue data it is really important to understand how it was generated, and what quality control measures were in place.
- Additionally, there can be variability between batches of materials and it is important to ensure the data used in modelling is representative of the material to be used in production parts.
- And always remember any CAE fatigue analysis is only as good as the materials data it is based on.

Thank You

Dr Michelle Hill
Head of Materials Testing

michelle.hill@hbkworld.com



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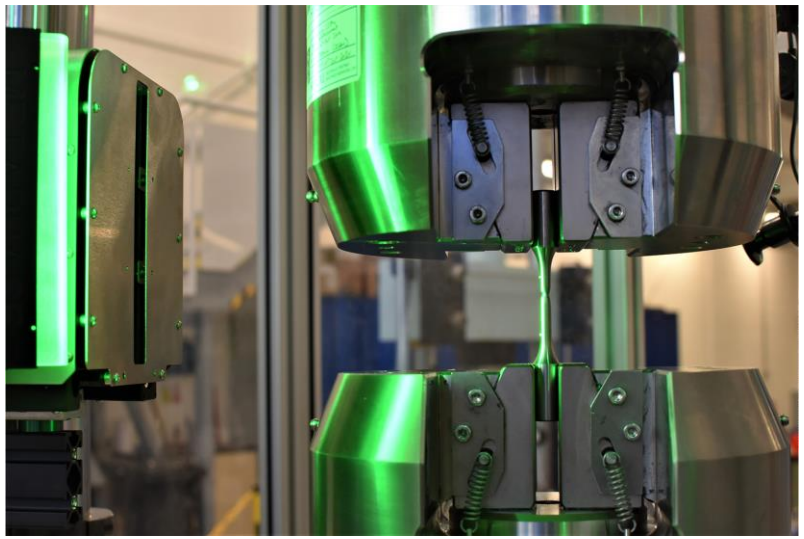

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